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ABSTRACT

Participation by women in scientific and technical careers is still low despite gains made by women in the United States job market. Consequently women's earning power and job opportunities as a group are diminished. Another effect is a loss of talent in the American work force. The objectives of this study were to: (1) study the rates of persistence of two classes (Fall 1984 and Fall 1985) of undergraduate women and men students in engineering and science from entry to graduation and (2) explore factors associated with persistence in these fields. Factors discussed in this paper are performance in mathematics and physics and mechanical experience and ability. The main question about persistence was whether the patterns of persistence, internal transfer, or withdrawal differed by gender. The patterns for men were almost identical while the patterns for women differed. For mathematics and physics there were no significant main effects for gender. There were significant main effects for persistence on mathematics and physics measures. Physics appeared to be a more citical filter for both male and female students in engineering and physical science. The link between persistence and mechanical ability was elusive. Implications of the study are discussed. References, figures, and tables are appended. (RT)

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# College Women's Persistence in Engineering and Physical Science: A Further Study

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## COLLEGE WOMEN'S PERSISTENCE IN ENGINEERING AND PHYSICAL SCIENCE: A FURTHER STUDY

Despite gains made by women in the U.S. job market in many areas, participation by women in scientific and technical careers is still very low (National Science Foundation [NSF], 1986). As a result women's earning power and job opportunities as a group are diminished. Another effect is a loss of talent in the American labor force which needs physical scientists and engineers, as well as social scientists and humanists, to help solve social problems and improve the quality of life (Koshland, 1988). Although, once trained, 93% of the women engineers (compared to 94% of men engineers) and 93% of both women and men physical scientists were employed in science or engineering fields in 1984 (NSF, 1986), women earn far fewer (13% to 16%) of the degrees in these areas than men (Berryman, 1983; Ellis, 1985, 1986; NSF, 1986). For this reason secondary school recruitment and college retention in engineering and physical science should be important concerns for educators and educational researchers. While there has been substantial research and development in the area of recruiting and preparing secondary school women for careers in mathematics and science, more work on retention is needed by those who do research on postsecondary education.

### Purpose of Study

The objectives of this study, which is in progress at the University of Maine (UM), are two-fold. One is to study the rates of persistence of two classes of undergraduate women and men students in the College of Engineering and Science from entry to graduation. The second purpose is to explore factors associated with persistence (or lack of it) in these fields, especially those factors which can be influenced by the undergraduate environment. The factors

to be discussed in this paper--performance in mathematics and physics and mechanical experience and ability--were chosen because they seemed intrinsically related to success in physical science and engineering and because gender-related differences in these areas had been observed in previous research, as will be discussed in the next section.

## Background

### Persistence

Studies specific to engineering indicate that time and school affect the complexity of the issue. Jagacinski and LeBold (1981) reported that at Purdue persistence rates of women were half those of men in the 1960s, but since 1970 the rates have been nearly equal. On the other hand, the Purdue freshmen class women of 1970, 1975, and 1980 appear to be more academically capable than the male students. Auster (1984) also provides evidence that women in engineering come from an "enriched" environment. LeBold and Shell (1980) controlled for students' rank in their high school class and Scholastic Aptitude Test (SAT) scores in their report of the 1976 Purdue freshmen and found a significantly lower retention rate for females than males. Gardner's (1976) study of Cornell University engineering students entering in 1974 indicated that men left engineering as often as women, but the men more often dropped out for academic reasons, and the women more often transferred to other programs.

The most comprehensive study of schools was Ott's study of retention in the 42 engineering schools enrolling the most women in the mid 1970s, reported by Corbett, Estler, Johnson, Ott, Robinson, and Shell (1980). She found that one and a half years after entry in 1975, despite identical first semester grade point averages (GPAs), the male's persistence rate was 73.3% as opposed to the female's rate of 67.8%, a difference significant at the .01 level. In a

subsample of 16 schools, persistence rates were higher for men at 13, higher for women at two, and equal at one. Again men were more likely to drop out for academic reasons and women to transfer to other programs. A recent study of the 1984 first-year engineers at Penn State indicated that being male was a significant predictor of higher engineering GPA (grades in Calculus 1 and 2, Physics 1, and Chemistry 1) and persistence into the second year (Levin & Wyckkoff, 1987). On the other hand, at the end of one year (1977-78), women in engineering at the University of Wisconsin-Madison had a 90% persistence rate compared to 81% for men (Greenfield, Holloway, & Remus, 1982).

In studies not specific to engineering the results are also mixed. Davis' (1975) study of students at the University of Minnesota's Institute of Technology noted that from 1961 to 1970 equal numbers of men and women dropped out for academic reasons, but a higher number of women dropped out for personal reasons. McNamara and Scherrei (1982) used the CIRP data, a nationwide sample of freshman entering college from 1971 to 1970; they found women less likely than men to persist in mathematics, science, or technology. Also minority women were especially underrepresented in these fields. An earlier study by Schonberger and Holden (1984) found that more men than women transferred out of science between their junior and senior years, but there were no differences between men and women transferring out of science between the freshman and sophomore years. However, those data were gathered retrospectively, did not include withdrawals, and were complicated by the inclusion of majors in life sciences.

In summary, it seems that with a few exceptions male students are more likely to persist in majoring in engineering and physical science. However, most of the studies involved students who began in 1980 or before, and since then change in women's participation in nontraditional careers is highly likely.

**Mathematics**

Gender-related differences in mathematics participation and performance have been of much research interest since Sells (1976) identified mathematics as the "critical filter" which confined female students to a few traditionally female college majors at the University of California, Berkeley. Hacker (1982) has documented the increased emphasis on mathematics, especially calculus, in U.S. baccalaureate programs in engineering over the last century and has hypothesized that this increase has constituted a barrier for women and minorities in these programs. Others have linked persistence in engineering programs to mathematics performance on the SATQ (Elkins & Leutkemeyer, 1974), and the College Entrance Examination Board's Math Achievement Test I (MACH1) (Durio, Kildow, & Slover, 1980). Sparrow (1987), using the High-School-and-Beyond data for women who had graduated from college by 1984, found that math ability, numbers of high school math courses taken, and good math grades in high school were among the most important predictors for majoring in math, science, or engineering.

There are two issues raised here about the connection between mathematics and physical science and engineering. One is whether women students entering such programs have less ability or background in mathematics as a group than men. The other is whether the relationship between mathematics and physical science or engineering is different for males and females. While several researchers (Ekstrom, 1986; Ferrini-Mundy & Balomenos, 1986) have documented that in the total population females do less well than males on the SATQ, in groups specifically choosing physical science or engineering, there is seldom any difference (Ferrini-Mundy & Balomenos, 1986; Schonberger & Holden, 1984; 1987). Data from both the 1984 and 1987 studies by Schonberger and Holden suggest that college calculus may be more closely linked to persistence in science and engineering for men than for women students. Ferrini-Mundy and

Balomenos noted that calculus achievement alone was not sufficient to explain lower persistence rates for women in the College of Engineering and Physical Science at the University of New Hampshire. It seems that the opinion still prevalent in the popular press (Coleman, 1987) that women do not become engineers and scientists because they cannot do the math should be examined more critically.

**Physics**

If research shows that mathematics is less important in differentiating male and female rates of persistence in engineering and physical science than popularly thought, then what academic area is more important? Intuitively physics seems to be an intermediary between theoretical mathematics and practical engineering. LeBold and Shell (1980) studied factors associated with first semester GPAs and persistence until the fifth semester by engineering students and found high school physics background to be as important as mathematics background. Students rated physics as an important factor influencing their decision to study engineering. Students with high GPAs and those persisting in engineering rated it higher than those with average or low GPAs and those who transferred or withdrew. A further analysis of the data (Jagacinski & LeBold, 1981) showed that significantly more men than women were influenced to study engineering by their experience in high school physics. Ferrini-Mundy and Balomenos (1986) found that for students in the College of Engineering and Science there was no significant difference between men's and women's grades in the first semester of college physics but in the second semester men did better. Schonberger and Holden (1987) also found that female and male students did equally well in the first semester of college physics. In that study college physics had all the earmarks of a critical filter for persistence in engineering and science.

**Mechanical Experience and Ability**

One of the most salient differences between physics and mathematics is the lab work and hands-on experience. The strong cultural mythology in the U.S. that men are good with things and women are good with people is reinforced by the fact that in the past gender-related differences in favor of men on the DAT Mechanical Reasoning Test (DATMech) have surpassed those of all other types of abilities (Bennett, Seashore, & Wesman, 1973). Although the test has been revised to eliminate gender bias in the illustrations, more recent studies (Holden & Schonberger, 1987; Schonberger & Holden, 1987) found highly significant differences in favor of males among college physics students taking the DATMech. Older studies have documented the usefulness of the DATMech in predicting success in engineering (Jones & McMillen, 1965; Wood & LeBold, 1968), but the gender ratios in colleges of engineering and science have changed in the past 20 years. Scherrei and McNamara's (1981) analysis of the CIRP data from 1971 to 1979 showed that mechanical ability was the most important correlate of receiving a bachelor's degree in engineering for whites as a group (men and women) and for women of other races as a group although the latter group was very small.

Mechanical <u>experience</u> is clearly still a gender issue as well. In Erikson's (1981) study of students in agricultural engineering, students were asked what they were best at or what they enjoyed working with the most: men more often chose mechanical devices; women more often chose plants. When asked why students they knew had dropped out of agricultural engineering, women more often than men listed inadequate mechanical skills. Hayden and Holloway (1985) document that minority nonpersisters came to study engineering believing that manual skills were not important, while persisters of all races believed that such skills were needed. Kahle's (1983) analysis of the NAEP data indicates that female students in elementary and secondary school have less experience

with machines and tools than male students. Schoenberger and Holden found in their 1984 and 1987 studies that women students had had less experience with common machines and tools before entering college than men students. Also in the 1984 study women more often than men reported that their mechanical skills were a problem for them in classwork or lab. Their 1987 studies found some differences in handling scientific equipment in high school classrooms as well as large differences in experience with common machines and tools outside the classroom.

## Method

### Data Collection

Data were collected from 537 first-year students in the College of Engineering and Science in Fall 1984 (F84) and Fall 1985 (F85). Since all colleges at UM require students to declare a major after at most four semesters, persistence was assessed by determining students' majors in fall of the junior year. Persistence categories were established based on these junior year majors: Category 1 = all the engineering majors plus physics and chemistry; Category 2 = engineering technology; Category 3 = life sciences; Category 4 = math and computer science; Category 5 = other internal transfers; and Category 6 = withdrawals (voluntary or involuntary). This variable was called PERSIST. Because of small cell sizes two new persistence variables were created by collapsing categories. In PERSIST2 Category 1 remained the same but Category 2 was all majors at UM (PERSIST's Categories 2-5) while Category 3 was the withdrawals. PERSIST3 had four categories: Category 1 was the same; Category 2 = majors with substantial math/science content not in Category 1 (PERSIST's Categories 2-4); Category 3 = majors with little math/science content (PERSIST's Category 5); and Category 4 was withdrawals. In other words, the first category was always the physical science or engineering majors, the last category was

always the withdrawals, and the middle one(s) were separated or combined transfers within the University.

Data on mathematics and physical science background and performance were provided by the institution. Numbers of math and science courses taken in high school were recorded on admission, as were college board scores (SATQ, SATV, MACH1, MACH2). All grades (tests, lab, recitation, final exam, and final course) from the required two-semester, calculus-based physics course (PHYS1, PHYS2) were available from the physics instructors. Final grades from the required, two-semester calculus courses (CALC1, CALC2) were also collected.

A subgroup of 437 students (205 in F84 and 232 in F85) took the 1982 revised (Form V) DATMech. In addition those 437 students filled out a questionnaire (HSX) about their high school experiences in math and science and another (TOOLS) about their mechanical experiences outside the classroom. The latter had been constructed for the authors' previous study by asking UM science professors to list common mechanical experiences which would be useful background for college courses in science or engineering. Students were asked to indicate how many times they had done, or helped to do, the tasks before they entered college. Choices were "never," "once," "twice," "3-5 times," or "6 or more times." The high school experience questionnaire also had 17 questions on whether or not students had <u>personally</u> used certain pieces of lab equipment ranging from a Bunsen burner to an oscilloscope. The choices were "yes," "no," or "not sure." The form of TOOLS used in this study has an alpha coefficient of 0.9307 and a corrected split-half reliability coefficient of 0.9256 (Holden & Schonberger, 1987).

**Data Analysis**

Various programs of SPSS$^X$ were used in analyzing the data including PEARSON CORR, CROSSTABS, CONDESCRIPTIVE, T-TEST, and ANOVA. Within the CROSSTABS program chi-square was the most frequently used statistic. However,

when the data were judged to be ordinal, the Kendall's tau-c statistic was also used. Because the number of the women in the study was small, subdivisions often led to small cell sizes. Because of these, the author experimented with the regression option and the hierarchical option in the ANOVA program. Since there was little difference in the results using either of these approaches compared to the classical approach, the last will be reported because it is most familiar. In addition, the Lawshe-Baker nomograph cited in Downie and Heath (1970) was used to compare the significance of differences between percentages.

## Results and Discussion

Campbell and Schwartz (1986) reported that nationally 18.0% of the freshmen entering engineering in Fall 1984 were women. The overall percentage of women students in engineering was 15.9% in 1984 according to Ellis (1985). The percentages of entering engineering students in this study who were women were somewhat less: 14.4% of the F84 whole group, 12.5% of the F85 whole group, and 13.4% of the combined groups. In the subgroups who took the DATMech and filled out the questionnaires the percentages of women were 14.1% for F84, 11.2% for F85, and 12.6% for the combined groups.

In an earlier paper (Schomberger & Holden, 1987), results from the F84 data were discussed both for the whole group of entering students and the subgroup who provided additional data. The purpose of this paper is to present the F85 results and the results from combining the two year's data. Since the whole group and subgroup F84 data results were essentially the same and are so again for the F85 data, only the subgroup results will be discussed here. These are the students about whom most information is available; they are 81% of the whole group.

For F84 the mean SATQ was 611 (611 males, 613 females); for F85 the mean was 609 (611 males, 594 females). The F84 SATV mean was 494 (492 males, 508 females); in F85 it was 493 (492 males, 502 females). None of these differences is statistically significant. A Kendall's tau-c analysis of the high school rank in class by gender indicated that the women ranked significantly ($p < .001$) higher both years. All of the women and 82% of the men were in the top 30% of their graduating classes. In summary, the women in this study represent a somewhat smaller percentage of the entering engineering students at UM than the national percentage of women, and they appear to be as able as the men.

**Persistence**

The main question about persistence was whether the patterns of persistence, internal transfer, or withdrawal differed by gender. The crosstabulation of persistence by gender produced some confusing results. While the persistence patterns for men in F84 and F85 were nearly identical, the patterns for women differed. (See Tables 1 and 2.) The percentages of internal transfers for women were essentially the same in F84 and F85, but the percentages of withdrawals and persistence in engineering and science differed. Institutional changes which might have produced this discrepancy were explored with the associate dean of the College of Engineering and Science. The one change that occurred was the admission of more marginal students into the college in F85. (It should be noted that SATQ mean for the F85 women was somewhat lower than that for the F84 women.) If anything, this should have produced the opposite persistence results, however. To check the possibility that marginal students were distorting the results the crosstabulations were run again with only those students who had ranked in the top 30% of their high school classes (Tables 3 and 4). This increased the significance of the gender difference in the F84 data, but did not change the discrepancy between the F84 and F85 women's data.

Part of this discrepancy may be due to the small numbers of women in the original pool: a few women making changes have a great effect. Pooling the two years' data might iron out the wrinkles. (See Table 5.) This analysis indicated that women's persistence rate in engineering and physical science (50.9%) was less than that of men (55.5%), but not significantly so. Another possible problem is the choice of the fifth semester as the checkpoint for persistence. Anecdotal evidence indicates that two of the F84 women transferred from engineering to mathematics in their sixth semester and two of the F85 women withdrew from school in the sixth semester. Graduation is a much more reliable checkpoint, but waiting for that requires persistence on the part of the researcher: past experience in the college indicates that less than 50% of these students can be expected to graduate in eight semesters, although the percentage will eventually peak at 70-75%.

Graduation data were available from the associate dean on students who entered the College of Engineering and Science in Fall 1982. If persistence in engineering and science is equated with graduation in the field by December 1987, internal transfers are equated with graduation from another college, and withdrawals are withdrawals, the results look similar to the combined group's crosstabulation with PERSIST2. (Compare Tables 5 and 6.) This shows that the persistence patterns have been fairly stable over a four-year time period and suggests what the graduation results may be for the F84 and F85 groups. A secondary analysis was done of the F82 data and the combined F84-85 data without the withdrawals (Tables 7 and 8). Significantly more of the F82 men graduated in engineering and more women graduated from other colleges ($p < .01$). This pattern was reported in both the studies by Gardner (1976) and by Corbett, Estler, Johnson, Ott, Robinson, and Shell (1980). The combined F84-85 data indicate a trend in that direction ($.10 < p < .05$), but it is too early to tell if the results will be replicated.

Unfortunately the wealth of data collected from the F84 and F85 groups was not available from the F82 group. The relationship of persistence to mathematics, physics, and mechanical ability and experience will be explored in the next sections.

**Mathematics**

Analysis of the mathematics data was guided by three questions.

1. Did women and men perform equally well on each of the mathematics measures?
2. Was there a significant relationship between mathematics and persistence?
3. Was the mathematical performance of men and women the same in each persistence category?

Two-way (gender by persistence) analyses of variance and *t*-tests were used to seek answers. Because the cell sizes in PERSIST were often small, the collapsed persistence variables PERSIST2 and PERSIST3 were used in the ANOVAs. (See Tables 9-12.)

There were no significant main effects for gender on either the SATQ or the MACH1 in the F84, F85, or combined groups. There had been a significant main effect for gender in the F84 data with women doing better than men in CALC1 and a trend ($p < .06$) toward the same for CALC2. However, those results were not replicated with the F85 data and disappeared in the combined group. None of the *t*-tests results were significant.

The results for persistence were quite different. With two exceptions there were significant main effects for both PERSIST2 and PERSIST3 on all mathematics measures in all groups of subjects, separately by year and combined. The two exceptions were the MACH1 scores of the F84 subjects and the SATQ scores of the F85 subjects. In fact, for those SATQ scores there was a trend ($.05 < p < .10$) toward a main effect for persistence.

The most interesting result of the ANOVAs done on the mathematics data was a significant gender-by-persistence interaction on the CALC1 scores. In the combined group all the persistence groups of women except those transferring to a nonscience major had CALC1 averages of C+ (2.33) or better. For the men in the combined group only the group of men who stayed in engineering and physical science had an average of C (2.00) or better. (See Figure 1.) Although in the smaller groups the results were not statistically significant, this pattern had been observed in the F84 data and was true with one exception (male students transferring to nonscience majors) in the F85 data. (See Figures 2 and 3.) The same pattern of interaction ($p = .108$) was noted in the combined group's results for CALC2: all the women's persistence groups averaged C or better except the group transferring to nonscience majors and none of the men's persistence groups except the one which stayed in engineering averaged C or better. It seems that in this study, the women, more so than the men, had the mathematics background necessary to continue in engineering and physical science.

**Physics**

The same questions that were asked about the math data were also asked of the physics data.

1. Did women and men perform equally well on each of the physics measures?
2. Was there a significant relationship between physics and persistence?
3. Was performance in physics the same for men and women in each persistence category?

Gender by persistence ANOVAs in the final grades and lab grades in PHYS1 again using PERSIST2 and PERSIST3 served to answer these questions (Tables 13 and 14). Too few students took the second semester of physics to do analyses of

variance on those data. Again t-tests were used as a second check for gender differences.

No gender differences were observed in the final grades or lab grades in physics for the F84, F85, or combined groups data using either the ANOVAs or the t-tests. Performance in physics seems to be critically linked to persistence in these data, however. Since the patterns of statistical significance were the same for all three groups, tables were constructed only for the combined group's data. The main effects for persistence on the final grade and lab grade were highly significant. Further examination of the cell means indicated that the only groups with a final physics average of C- or better were those persisting in engineering and physical science. More so than mathematics, physics seems to be a critical filter for both male and female students in engineering and physical science.

Because more extensive sets of data were available from the physics instructors than were available for calculus, it was possible to track students down a persistence pipeline in physics. The checkpoints were starting PHYS1, finishing PHYS1, passing PHYS1, starting PHYS2, finishing PHYS2 and passing PHYS2. At each checkpoint the percent of the original pool was calculated for men and women and the two percents compared for significance of difference. Because the DATMech and the questionnaires had been given in physics class part way through the first semester and some students had already dropped the course, using the tested subgroups would have distorted the pipeline results. Therefore, for this analysis only, data for all first-year engineering and physical science students were used.

In the F84 group the pipeline had been leakier for women than for men with the significantly different leaks occurring at choice points--sticking it out in the first semester and choosing to take the second semester. In the F85 group the pipeline was also leakier overall for women than for men. This time the

only significantly ($p < .05$) different leak was sticking it out in the first semester; essentially the same percent of women and men passing the first semester chose to take the second semester. (See Table 15.) The significance pattern in the combined group's data looked like that of the F84 data. (See Table 16.) The significant leaks for women were finishing the first semester and starting the second semester of physics; once they started, the attrition rates did not differ significantly by gender.

What could account for these differences? Although the CROSSTABS analysis of the admissions data indicated that female and male students were equally as likely to have taken calculus in high school, the male students were more likely to have taken a year or two of physics. In other words, high school preparation may have been a factor. Confidence could also have been a factor: male students responded more positively than female students to an item on the high school experience questionnaire about how well their high school science background had prepared them for college physics.

**Mechanical Experience and Ability**

Again the same three questions were asked as were asked about physics and mathematics.

1. Did women and men have equal mechanical ability and experience?
2. Was mechanical ability and experience significantly related to persistence?
3. Was the mechanical ability and experience of men and women the same in each persistence category?

Two-way (gender by persistence) ANOVAs and *t*-tests were performed on the scores from the DATMech and TOOLS and on the lab grades from the first semester of physics. Crosstabulation was done on the lab equipment portion of the HSX and the separate TOOLS items.

As found in the F84 data, gender-related differences in mechanical ability and experience were substantial. This is shown by the ANOVAs on the DATMech (Table 17 and 18) and TOOLS (Table 19 and 20) and was confirmed by t-tests. Again the contrast between experiences inside and outside the classroom was striking. Of the 42 items in TOOLS the men had used 34 significantly more often, the women had used 3 items (all related to homemaking) more often, and for 5 items there was no difference. For the 13 pieces of high school lab equipment there were no differences in the F84 data. In the F85 group women were less sure if they had used a pan balance or an oscilloscope and reported less experience with an analytical balance. These results were replicated in the combined group with the addition that women reported less experience with a ripple tank. However, overall the differences were scarce compared to the out-of-class experiences. Significantly more men than women had taken shop or mechanical drawing in high school. There were no gender differences in the physics lab grades.

The link between persistence and mechanical ability or experience was weak, however. The ANOVAs of neither the DATMech nor the TOOLS scores showed a main effect for persistence. The only measure which did have a main effect for persistence was the PHYS1 lab grades. It had been suspected that the DATMech and TOOLS would be highly correlated with the PHYS1 lab grades, but that did not prove to be the case.

An interaction in the F84 DATMech and PHYS1 lab-grade data similar to that found in the CALC1 data (Figures 1-3) had suggested that mechanical ability and experience were a critical filter only for women in engineering and science, although the interaction was not statistically significant. The pattern in the F85 DATMech data was quite different from the F84 data and the F85 PHYS1 lab grades were enough different so the significance of that interaction was only .114.

It is puzzling that these variables which seem so intrinsically related to success in engineering and science and on which the gender difference is so pronounced have shed so little light on the scene.

## Implications

### For Further Research

The problems in assessing persistence noted earlier can be solved by waiting until these students can be expected to have graduated. Then at least beginning and ending majors can be compared. Furthermore, a method of tracking students through majors (Simpson, 1987) has very recently come to the author's attention. It should be possible to go back into the institutional data and use that method to chart intermediary choices of major and to get some idea of when students change their majors.

Another direction the research could take is a more intensive study of the withdrawals. The male students' GPAs and those of the F84 women were less than the 2.00 required for graduation, but all of the F85 women who withdrew had GPAs greater than 2.00. The possibility that some of the withdrawals were successful at another institution should be investigated.

The possibility that nonacademic factors, such as social support for women in majors where they are in the small minority, may have influenced both withdrawal and internal transfer has yet to be investigated. Besides administering a questionnaire developed for an earlier study (Schonberger & Holden, 1984), students could be interviewed about their choices. One such interview of a female student with a very high GPA who transferred from engineering to mathematics in her sixth semester has already taken place. The fact that in Ott's study some schools had higher persistence rates for women than men suggests that institution-specific factors ought to be investigated.

The mechanical connection has so far proved elusive, at least as an explanation for women's persistence in engineering and physical science. There may be some other ways to examine that data, or a better measure of persistence may improve the connection.

**For Educational Practice**

This group of women entered engineering and science with adequate skills in math and continued to perform well in calculus. Mathematics did appear to be a critical filter for men, however. Perhaps some of the programs developed by the women and mathematics movement could help them.

Physics was a problem for everyone, however. Although women who stuck with the course did as well as men, there were persistence differences for women in the physics pipeline. They may need extra encouragement not to drop the course at the first low test grade. It will be interesting to see if the hiring of the first woman in the physics department in Fall 1986 changes this pattern. It will also be important to educate high school teachers and guidance counselors about the importance of high school physics for engineering-bound women. Much progress has been made convincing high school women of the necessity of taking math; now the same needs to be done for physical sciences.

If the mechanical connection does develop on further examination, strategies should be developed to build mechanical skill and self-confidence. Based on the results of the study reported here however, such recommendations would be premature.

## Summary

The purpose of this study was to analyze data from the second year and combined years of a study on persistence of college women and men in engineering and physical science. Although the results are tentative because the students were only in their fifth semester when persistence was assessed, it appears that by graduation a smaller percentage of women than men will finish in engineering

and physical science and more will earn degrees in other areas. Calculus grades seemed to be an important determinant of persistence for men and physics was important for everyone. The mechanical connection remained elusive.

## References


Auster, C. J. (1984). Nontraditional occupational choice: A comparative study of women and men in engineering. (Doctoral dissertation, Princeton University, 1984). Dissertation Abstracts International, 44, 3511A.

Bennett, G. K., Seashore, H. G., & Wesman, A. G. (1973). Differential aptitude tests: Administrator's handbook. New York: The Psychological Corporation.

Berryman, S. E. (1983, November). Who Will Do Science? New York: The Rockefeller Foundation.

Boli, J., Allen, M. L., & Payne, A. (1983, April). Women and men in introductory undergraduate mathematics and chemistry courses. Paper presented at the annual meeting of the American Educational Research Association, Montreal.

Campbell, P. B. & Schwartz, S. S. (1986). An investigation of women in engineering education: Enrollment patterns, barriers, special programs for women at Stevens. Hoboken, NJ: Office of Special Programs for Women, Stevens Institute of Technology.

Coleman, D. (Aug. 2, 1987). Girls and math: Is biology really destiny? New York Times, Education Life, section 12, 42-46.

Corbett, J. G., Estler, S., Johnston, W., Ott, M. D., Robinson, H. & Shell, G. R. (1980). Women in engineering: An exploratory study of enrollment factors in the seventies. (Contract No. 400-77-0004.) Washington, DC: National Institute of Education.

Davis, S. O. (1975). Researcher's eye view: Women students, technical majors, and retention. IEEE Transactions on Education, E-18 (1), 25-29.

Downie, N. M. & Heath, R. W. (1970). Basic Statistical Methods (3rd ed.). New York: Harper & Row, Publishers.

Durio, H. F., Kildow, C. A., & Slover J. T. (1980, April). Ethnicity and sex differences in the use of college entrance examinations, mathematics achievement, and high school rank as predictors of performance and retention among engineering students. Paper presented at the annual meeting of the American Education Research Association, Boston, MA. ERIC Document Reproduction Service No. ED 185-119.

Ekstrom, R. B. (1986, November). Untitled paper presented at the midyear conference of the American Educational Research Association's Special Interest Group-Research on Women in Education, Washington, DC.

Elkins, R. L. & Luetkemeyer, J. F. (1974). Characteristics of successful freshmen engineering students. Engineering Education, 65 (2), 189-191.

Ellis, R. A. (1985, November). Engineering enrollments, fall 1984. Engineering Education, 76 (2), 102-108.

Ellis, R. A. (1986, October). Engineering and engineering technology enrollments, fall 1985. 77 (1), Engineering Education, 57-66.

Erickson, L. R. (1981). Women in engineering: Attitudes, motivations and experiences. Engineering Education, 72 (2), 180-182.

Ferrini-Mundy, J. & Balomenos, R. H. (1986). Calculus as a filter: Academic and career choices of college men and women. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Gardner, R. E. (1976). Women in engineering: The impact of attitudinal differences on educational institutions. Engineering Education, 67 (3), 233-240.

Greenfield, L. B., Holloway, E. L., & Remus, L. (1982, November). Women students in engineering: Are they so different from men? Journal of College Student Personnel, 508-511.

Hacker, S. L. (1983). Mathematization of engineering: Limits on women and the field. In J. Rothschild (Ed.), Machina Ex Dea (pp. 38-58). New York: Permagon Press.

Hayden, D. C. & Holloway, E. L. (1985, April). A longitudinal study of attrition among engineering students. Engineering Education, 75 (7) 664-668.

Holden, C. C. & Schonberger, A. K. (1987, July). Women enrolled in a university physics course: The mechanical connection. Paper presented at the Third International Interdisciplinary Congress on Women, Dublin, Ireland.

Jagacinski, C. M. & LeBold, W. K. (1981). A comparison of men and women undergraduate and professional engineers. Engineering Education, 72 (3), 213-220.

Jones, C. W. & McMillen, D. (1965). Engineering freshman norms for the DAT mechanical reasoning and space relations tests utilizing fifteen-minute time limits. Educational and Psychological Measurement, 25, 459-464.

Kahle, J. B. (1983). The disadvantaged majority: Science education for women. AETS Outstanding Paper for 1983. Burlington, NC: Carolina Biological Supply Company.

Koshland, D. E. (1988). Women in Science. Science, 239 (4847), 1473.

LeBold, W. K. (1982). Putting it all together: A model program for women entering engineering. Newton, MA: Educational Development Center.

LeBold, W. K. & Shell, K. D. (1980). The utility of cognitive and noncognitive information in predicting engineering retention and selection of specialization. 1980 Frontiers in Education Conference (ASEE Annual Conference, 504-510.

Levin, J. & Wyckhoff, J. (1987, April). Identification of predictors of persistence and success for students admitted to baccalaureate engineering programs of study. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC.

McNamara, P. P. & Scherrei, R. A. (1982). College women pursuing careers in science, mathematics, and engineering in the 1970s. (NSF Report No. FGK 57295). Washington, DC: National Science Foundation. ERIC Document Reproduction Service No. ED 217-778.

National Science Foundation. (1986). Women and minorities in science and engineering. (NSF 86-301). Washington, DC.

Scherrei, R. A. & McNamara, P. P. (1981, October). Factors that describe and encourage women who pursue scientific and engineering careers. Paper presented at the mid-year conference of the American Educational Research Association's Special Interest Group-Research on Women in Education, Washington, DC.

Schonberger, A. K. & Holden, C. C. (1984, April). Women as university students in science and technology: What helps them stick with it? Paper presented at the annual meeting of the New England Educational Research Organization, Rockport, ME.

Schonberger, A. K. & Holden C. C. (1987, April). College women's persistence in engineering and physical science: The mechanical connection. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC.

Sells, L. W. (1976, February). The mathematics filter and the education of women and minorities. Paper presented at the annual meeting of the American Association for the Advancement of Science, Boston, MA.

Simpson, W. A. (1987). Tracking students through majors: Methodology and application. Journal of Higher Education, 58 (3), 323-343.

Sparrow, K. G. (1987, April). A profile differentiating female college science majors from nonscience majors: A predictor set of variables. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC.

SPSS, Inc. (1986). SPSS$^{X}$ user's guide. (2nd ed.). Chicago.

Vetter, B. M. Women's progress. Mosaic, 18 (1), 2-9.

Wood, D. A. & LeBold, W. K. (1968). Differential and overall prediction of academic success in engineering: The complementary role of DAT, SAT and HSR. Educational and Psychological Measurement, 28, 1223-1228.

**Figure 1**
**CALC1 Cell Means, Gender by Persist3**
**Combined Group**

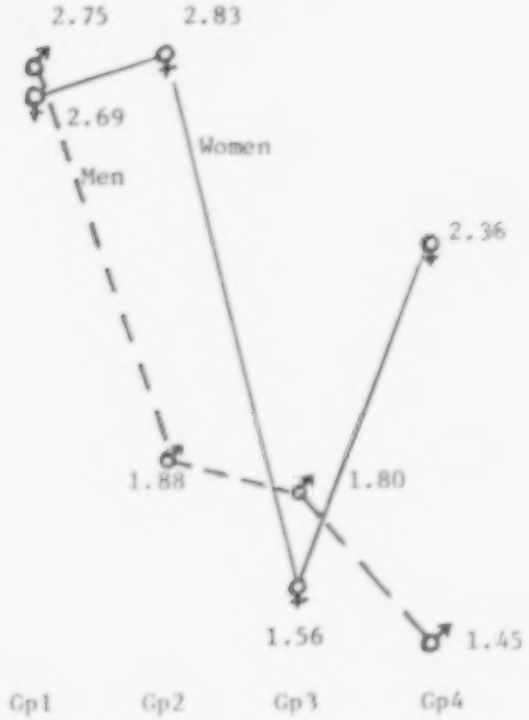


**Figure 2**
**CALC1 Cell Means, Gender by PERSIST3**
**F84 Group**

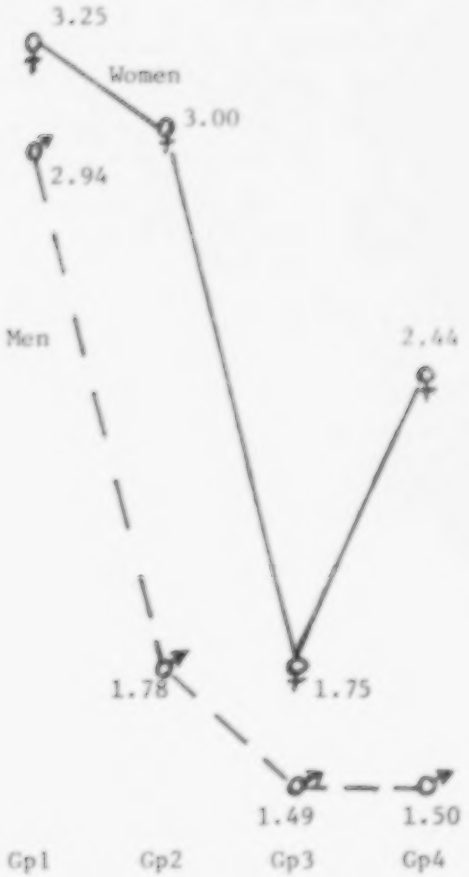


**Figure 3**
**CALC1 Cell Means, Gender by Persist3**
**F85 Group**

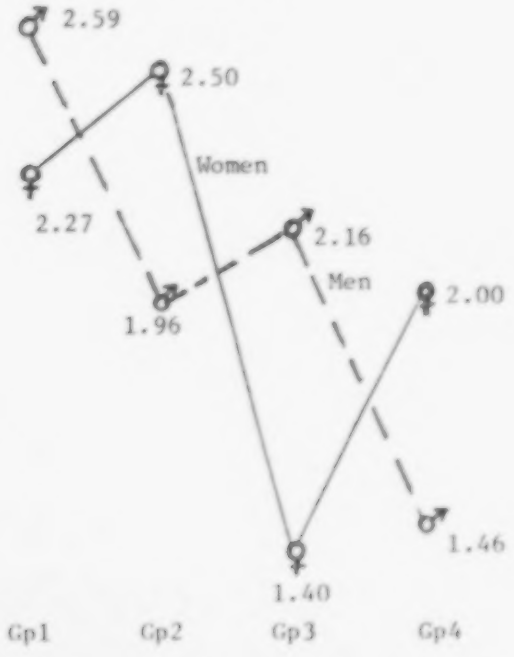

Table 1

Crosstabulation of Persistence by Gender in the F84 Group (n=205)

PERSIST

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 97<br>55.1 | 12<br>41.4 |
| Engineering<br>Tech. | 6<br>3.4 | 1<br>3.4 |
| Life Science | 6<br>3.4 | 1<br>3.4 |
| Math/Computer<br>Science | 3<br>1.7 | 2<br>6.9 |
| Other Transfers | 17<br>9.7 | 4<br>13.8 |
| Withdrew | 47<br>26.7 | 9<br>31.0 |
| TOTAL | 176 | 29 |

Chi-square = 4.22152

df = 5, p = .5180

Kendall's tau-c = .05930

p = .1238

PERSIST 2

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 97<br>55.1 | 12<br>41.4 |
| Internal<br>Transfers | 32<br>18.2 | 8<br>27.6 |
| Withdrew | 47<br>26.7 | 9<br>31.0 |
| TOTAL | 176 | 29 |

Chi-square = 2.18269

df = 2, p = .3358

Kendall's tau-c = .05835

p = .1267

PERSIST 3

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 97<br>55.1 | 12<br>41.4 |
| Science<br>Transfers | 15<br>8.5 | 4<br>13.8 |
| Nonscience<br>Transfers | 17<br>9.7 | 4<br>13.8 |
| Withdrew | 47<br>26.7 | 9<br>31.0 |
| TOTAL | 176 | 29 |

Chi-square = 2.21570

df = 3, p = .5289

Kendall's tau-c = .05758

p = .1306

Table 2

Crosstabulation of Persistence by Gender in the F85 Group (n=232)

PERSIST

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 115<br>55.8 | 16<br>61.5 |
| Engineering<br>Tech. | 12<br>5.8 | 0<br>0 |
| Life Science | 3<br>1.5 | 1<br>3.8 |
| Math/Computer<br>Science | 2<br>1.0 | 2<br>7.7 |
| Other Transfers | 16<br>7.8 | 5<br>19.2 |
| Withdrew | 58<br>28.2 | 2<br>7.7 |
| TOTAL | 206 | 26 |

Chi-square = 15.55175

df = 5, p = .0082

Kendall's tau-c = -.04660

p = .1338

PERSIST 2

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 115<br>55.8 | 16<br>61.5 |
| Internal<br>Transfers | 33<br>16.0 | 8<br>30.8 |
| Withdrew | 58<br>28.2 | 2<br>7.7 |
| TOTAL | 206 | 26 |

Chi-square = 6.71340

df = 2, p = .0349

Kendall's tau-c = -.05232

p = .1108

PERSIST 3

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 115<br>55.8 | 16<br>61.5 |
| Science<br>Transfers | 17<br>8.3 | 3<br>11.5 |
| Nonscience<br>Transfers | 16<br>7.8 | 5<br>19.2 |
| Withdrew | 58<br>28.2 | 2<br>7.7 |
| TOTAL | 206 | 26 |

Chi-square = 7.51233

df = 3, p = .0572

Kendall's tau-c = -.04957

p = .1240

Table 3

Crosstabulation of Persistence by Gender in the F84 Top 3 High School Ranks

PERSIST

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/ Phys. Sci. | 77<br>57.0 | 10<br>37.0 |
| Engineering Tech. | 5<br>3.7 | 1<br>3.7 |
| Life Science | 4<br>3.0 | 1<br>3.7 |
| Math/Computer Science | 3<br>2.2 | 2<br>7.4 |
| Other Transfers | 14<br>10.4 | 4<br>14.8 |
| Withdrew | 32<br>23.7 | 9<br>33.3 |
| TOTAL | 135 | 27 |

Chi-square = 4.90025

df = 5, p = .4282

Kendall's tau-c = .10852

p = .0393

PERSIST 2

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/ Phys. Sci. | 77<br>57.0 | 10<br>37.0 |
| Internal Transfers | 26<br>19.3 | 8<br>29.6 |
| Withdrew | 32<br>23.7 | 9<br>33.3 |
| TOTAL | 135 | 27 |

Chi-square = 3.65319

df = 2, p = .1610

Kendall's tau-c = .10776

p = .0397

PERSIST 3

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/ Phys. Sci. | 77<br>57.0 | 10<br>37.0 |
| Science Transfers | 12<br>8.9 | 4<br>14.8 |
| Nonscience Transfers | 14<br>10.4 | 4<br>14.8 |
| Withdrew | 32<br>23.7 | 9<br>33.3 |
| TOTAL | 135 | 27 |

Chi-square = 3.70025

df = 3, p = .2957

Kendall's tau-c = .10654

p = .0420

Table 4

Crosstabulation of Persistence by Gender in the F85 Top 3 High School Ranks

PERSIST

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 93<br>63.3 | 14<br>60.9 |
| Engineering<br>Tech. | 9<br>6.1 | 0<br>0 |
| Life Science | 2<br>1.4 | 1<br>4.3 |
| Math/Computer<br>Science | 1<br>0.7 | 2<br>8.7 |
| Other Transfers | 9<br>6.1 | 4<br>17.4 |
| Withdrew | 33<br>22.4 | 2<br>8.7 |
| TOTAL | 147 | 23 |

Chi-square = 14.80244

df = 5, p = .0112

Kendall's tau-c = .00789

p = .4401

PERSIST 2

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 93<br>63.3 | 14<br>60.9 |
| Internal<br>Transfers | 21<br>14.3 | 7<br>30.4 |
| Withdrew | 33<br>22.4 | 2<br>8.7 |
| TOTAL | 147 | 23 |

Chi-square = 4.99443

df = 2, p = .0823

Kendall's tau-c = -.01495

p = .3873

PERSIST 3

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Sci. | 93<br>63.3 | 14<br>60.9 |
| Science<br>Transfers | 12<br>8.2 | 3<br>13.0 |
| Nonscience<br>Transfers | 9<br>6.1 | 4<br>17.4 |
| Withdrew | 33<br>22.4 | 2<br>8.7 |
| TOTAL | 147 | 23 |

Chi-square = 5.68483

df = 3, p = .1280

Kendall's tau-c = -.01204

p = .4089

Table 5

Crosstabulation of Persistence by Gender in the Combined Group (n=437)

PERSIST

| Count / Col % | Males | Females |
|---|---|---|
| Engineering/ Phys. Sci. | 212<br>55.5 | 28<br>50.9 |
| Engineering Tech. | 18<br>4.7 | 1<br>1.8 |
| Life Science | 9<br>2.4 | 2<br>3.6 |
| Math/Computer Science | 5<br>1.3 | 4<br>7.3 |
| Other Transfers | 33<br>8.6 | 9<br>16.4 |
| Withdrew | 105<br>27.5 | 11<br>20.0 |
| TOTAL | 382 | 55 |

Chi-square = 13.72678

df = 5, p = .0174

Kendall's tau-c = .00369

p = .4557

PERSIST 2

| Count / Col % | Males | Females |
|---|---|---|
| Engineering/ Phys. Sci. | 212<br>55.5 | 28<br>50.9 |
| Internal Transfers | 65<br>17.0 | 16<br>29.1 |
| Withdrew | 105<br>27.5 | 2<br>20.0 |
| TOTAL | 382 | 55 |

Chi-square = 4.98162

df = 2, p = .0828

Kendall's tau-c = -.00002

p = .4997

PERSIST 3

| Count / Col % | Males | Females |
|---|---|---|
| Engineering/ Phys. Sci. | 212<br>55.5 | 28<br>50.9 |
| Science Transfers | 32<br>8.4 | 7<br>12.7 |
| Nonscience Transfers | 33<br>8.6 | 9<br>16.4 |
| Withdrew | 105<br>27.5 | 11<br>20.0 |
| TOTAL | 382 | 55 |

Chi-square = 5.20420

df = 3, p = .1574

Kendall's tau-c = .00117

p = .4859

Table 6

Persistence Data for Students Entering the College of Engineering and Science in Fall 1982

n = 238

| | Males | | Females | |
|---|---|---|---|---|
| | n | % of 199 | n | % of 39 |
| Entering in 9/82 | 199 | 100% | 39 | 100% |
| Graduated by 6/86 | 81 | 40.7% | 21 | 53.8% |
| Graduated by 12/87 | 136 | 68.3% | 31 | 79.5% |
| In Engineering/ Phys. Sci. | 114 | 57.3% | 19 | 48.7% |
| In another College | 22 | 11.1% | 12 | 30.7% |
| Still enrolled | 8 | 4.0% | 5 | 12.8% |
| Withdrew | 52 | 26.1% | 3 | 7.7% |

Table 7

Crosstabulation of Major at Graduation by Gender
of Fall 1982 Entrants into the College of Engineering
and Science

n = 167

| Count<br>Col % | Males | Females |
|---|---|---|
| Graduated in<br>Engineering & Science | 114<br>83.8% | 19<br>61.3% |
| Graduated in<br>another College | 22<br>16.2% | 12<br>38.7% |
| Total | 136 | 31 |

Chi Square = 7.906
df = 1
$p < .01$

Table 8
Crossstabulation of Persistence by Gender of Students
Remaining at this University

Whole Group - Withdrawals
n = 321

| Count<br>Col % | Males | Females |
|---|---|---|
| Engineering/<br>Phys. Science | 212<br>76.5% | 28<br>63.6% |
| Internal Transfers | 65<br>23% | 16<br>36.4% |
| Total | 277 | 44 |

Chi Square = 3.348
df = 1
$.05 < p < .10$

Table 9

College Board Mathematics Scores by Gender by Persistence

F84 (n=205)

| Source of Variation | Sum of Squares | Df | Mean Square | F | P |
|---|---|---|---|---|---|
| | SATQ (n=202) | | | | |
| Main Effects | 40783 | 3 | 13594 | 3.199 | .024 |
| Gender | 917 | 1 | 917 | .216 | .643 |
| PERSIST2 | 40665 | 2 | 20333 | 4.785 | .009 |
| Main Effects | 41251 | 4 | 10313 | 2.417 | .050 |
| Gender | 891 | 1 | 891 | .209 | .648 |
| PERSIST3 | 41133 | 3 | 13711 | 3.213 | .024 |
| | MACH1 (n=168) | | | | |
| Main Effects | 107542 | 3 | 35847 | 2.121 | .100 |
| Gender | 37904 | 1 | 37904 | 2.242 | .136 |
| PERSIST2 | 81558 | 2 | 40779 | 2.412 | .093 |
| Main Effects | 108856 | 4 | 27214 | 1.595 | .178 |
| Gender | 37504 | 1 | 37504 | 2.198 | .140 |
| PERSIST3 | 82871 | 3 | 27624 | 1.619 | .187 |

F85 (n=232)

| Source of Variation | Sum of Squares | Df | Mean Square | F | P |
|---|---|---|---|---|---|
| | SATQ (n=232) | | | | |
| Main Effects | 31557 | 3 | 10519 | 3.199 | .090 |
| Gender | 5016 | 1 | 5016 | 1.046 | .308 |
| PERSIST2 | 25172 | 2 | 12586 | 2.624 | .075 |
| Main Effects | 37128 | 4 | 9282 | 1.930 | .107 |
| Gender | 5523 | 1 | 5523 | 1.148 | .285 |
| PERSIST3 | 30743 | 3 | 10248 | 2.130 | .097 |
| | MACH1 (n=152) | | | | |
| Main Effects | 89974 | 3 | 29991 | 5.830 | .001 |
| Gender | 9062 | 1 | 9062 | 1.761 | .187 |
| PERSIST2 | 80912 | 2 | 40456 | 7.864 | .001 |
| Main Effects | 90251 | 4 | 22563 | 4.340 | .002 |
| Gender | 10700 | 1 | 10700 | 2.058 | .154 |
| PERSIST3 | 81189 | 3 | 27063 | 5.205 | .002 |

Table 10

ANOVAs of College Board Mathematics Scores by Gender by Persistence

Combined Years (n=538)

SATQ (n=427)

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 64167 | 3 | 21389 | 4.733 | .003 |
| Gender | 481 | 1 | 481 | .106 | .744 |
| PERSIST3 | 62029 | 2 | 31015 | 6.863 | .001 |
| Main Effects | 65384 | 4 | 16346 | 3.612 | .007 |
| Gender | 501 | 1 | 501 | .111 | .740 |
| PERSIST3 | 63245 | 3 | 21082 | 4.659 | .003 |

MACH1 (n=320)

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 143107 | 3 | 47702 | 4.229 | .006 |
| Gender | 5609 | 1 | 5609 | .491 | .481 |
| PERSIST2 | 139993 | 2 | 69997 | 6.205 | .002 |
| Main Effects | 144209 | 4 | 36052 | 3.181 | .014 |
| Gender | 5809 | 1 | 5809 | .513 | .475 |
| PERSIST3 | 141095 | 3 | 47032 | 4.149 | .007 |

Table 11

Calculus Grades by Gender by Persistence

F84 (n=205)

| Source of Variation | Sum of Squares | Df | Mean Square | F | P |
|---|---|---|---|---|---|
| CALC1 (n=216) | | | | | |
| Main Effects | 86.6 | 3 | 28.9 | 23.938 | .000 |
| Gender | 9.3 | 1 | 9.3 | 7.678 | .006 |
| PERSIST2 | 81.8 | 2 | 40.9 | 33.917 | .000 |
| 2-way Interaction | 1.9 | 2 | 1.0 | .802 | .450 |
| Main Effects | 88.9 | 4 | 22.2 | 18.550 | .000 |
| Gender | 9.1 | 1 | 9.1 | 7.625 | .006 |
| PERSIST3 | 84.1 | 3 | 28.0 | 23.398 | .000 |
| 2-way Interaction | 3.4 | 3 | 1.1 | .943 | .421 |
| CALC2 (n=156) | | | | | |
| Main Effects | 48.0 | 3 | 16.0 | 14.556 | .000 |
| Gender | 4.1 | 1 | 4.1 | 3.743 | .055 |
| PERSIST2 | 46.5 | 2 | 23.3 | 21.144 | .000 |
| 2-way Interaction | 5.6 | 1 | 2.8 | 2.533 | .083 |
| Main Effects | 48.4 | 4 | 12.1 | 10.919 | .000 |
| Gender | 4.0 | 1 | 4.0 | 3.625 | .059 |
| PERSIST3 | 46.9 | 3 | 15.6 | 14.102 | .000 |
| 2-way Interaction | 6.0 | 2 | 2.0 | 1.810 | .148 |



F85 (n=232)

| Source of Variation | Sum of Squares | Df | Mean Square | F | P |
|---|---|---|---|---|---|
| CALC1 (n=193) | | | | | |
| Main Effects | 50.0 | 3 | 16.7 | 12.159 | .000 |
| Gender | 1.3 | 1 | 1.3 | 0.928 | .33 |
| PERSIST2 | 49.9 | 2 | 25.0 | 18.200 | .000 |
| 2-way Interaction | 1.4 | 2 | 0.7 | .526 | .59 |
| Main Effects | 50.0 | 4 | 12.5 | 9.097 | .000 |
| Gender | 1.3 | 1 | 1.3 | 0.909 | .34 |
| PERSIST3 | 49.9 | 3 | 16.6 | 12.104 | .000 |
| 2-way Interaction | 3.5 | 3 | 1.2 | .842 | .47 |
| CALC2 (n=186) | | | | | |
| Main Effects | 43.5 | 3 | 14.5 | 11.857 | .000 |
| Gender | 0.2 | 1 | 0.2 | .133 | .71 |
| PERSIST2 | 43.5 | 2 | 21.7 | 17.786 | .000 |
| 2-way Interaction | 0.1 | 1 | 0.1 | .109 | .74 |
| Main Effects | 45.5 | 4 | 11.4 | 9.397 | .000 |
| Gender | 0.2 | 1 | 0.2 | .186 | .66 |
| PERSIST3 | 45.5 | 3 | 15.2 | 12.529 | .000 |
| 2-way Interaction | 2.2 | 2 | 1.1 | .921 | .40 |

Table 12

ANOVAs of Calculus Grades by Gender by Persistence

Combined Years (n=437)

CALC1 (n=409)

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 121.0 | 3 | 40.3 | 30.603 | .000 |
| Gender | 2.2 | 1 | 2.2 | 1.698 | .193 |
| PERSIST2 | 118.8 | 2 | 59.4 | 45.068 | .000 |
| 2-way Interaction | 6.7 | 2 | 3.3 | 2.531 | .081 |
| Main Effects | 122.7 | 4 | 30.7 | 23.418 | .000 |
| Gender | 2.4 | 1 | 2.4 | 1.827 | .177 |
| PERSIST3 | 120.5 | 3 | 40.2 | 30.664 | .000 |
| 2-way Interaction | 11.0 | 3 | 3.7 | 2.787 | .040 |

CALC2 (n=342)

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 85.8 | 3 | 28.6 | 24.259 | .000 |
| Gender | 1.3 | 1 | 1.3 | 1.073 | .301 |
| PERSIST2 | 85.0 | 2 | 42.5 | 36.032 | .000 |
| 2-way Interaction | 3.6 | 2 | 1.8 | 1.535 | .217 |
| Main Effects | 86.1 | 4 | 21.5 | 18.328 | .000 |
| Gender | 1.3 | 1 | 1.3 | 1.068 | .302 |
| PERSIST3 | 85.3 | 3 | 28.4 | 24.199 | .000 |
| 2-way Interaction | 7.2 | 3 | 2.4 | 2.043 | .108 |

Table 13

ANOVAs of First Semester Physics Final Grades by Gender by Persistence

Combined Groups (n=437)

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effect | 152.6 | 3 | 50.9 | 39.598 | .000 |
| Gender | 0.9 | 1 | 0.9 | .698 | .404 |
| PERSIST2 | 150.9 | 2 | 75.5 | 58.729 | .000 |
| Main Effect | 153.8 | 4 | 38.4 | 29.864 | .000 |
| Gender | 0.9 | 1 | 0.9 | .661 | .417 |
| PERSIST3 | 152.1 | 3 | 50.7 | 39.374 | .000 |

Table 14

ANOVAs on First Semester Physics Lab Grades by Gender by Persistence

Combined Groups (n=437)

| Variation | Source of Squares | Sum of Df | Square | Mean F | p |
|---|---|---|---|---|---|
| Main Effects | 4134 | 3 | 1378 | 16.694 | .000 |
| Gender | 7.7 | 1 | 7.7 | .093 | .761 |
| PERSIST2 | 4132 | 2 | 2066 | 25.029 | .000 |
| Main Effects | 4209 | 4 | 1052 | 12.793 | .000 |
| Gender | 615 | 1 | 6.5 | .079 | .778 |
| PERSIST3 | 4207 | 3 | 1402 | 17.049 | .000 |

Table 15

Persistence in Physics by Gender

F85 Subgroup

| | Males | | Females | |
|---|---|---|---|---|
| | n | % of 223 | n | % of 32 |
| Entered the College of Engineering and Science and started PHYS1 | 223 | 100% | 32 | 100% |
| Finished PHYS1* | 202 | 91% | 24 | 75% |
| Passed PHYS1 | 161 | 72% | 18 | 56% |
| Started PHYS2 | 139 | 62% | 16 | 50% |
| Finished PHYS2 | 134 | 60% | 15 | 47% |
| Passed PHYS2 | 125 | 56% | 13 | 41% |

* Points at which the female and male percentages are significantly different at the .05 level.

Table 16

Persistence in Physics by Gender

Combined Groups

| | Males | | Females | |
|---|---|---|---|---|
| | n | % of 419 | n | % of 64 |
| Entered the College of Engineering and Science and started PHYS1 | 419 | 100% | 64 | 100% |
| Finished PHYS1 ** | 384 | 92% | 50 | 78% |
| Passed PHYS1 | 278 | 66% | 36 | 56% |
| Started PHYS2 * | 249 | 59% | 28 | 44% |
| Finished PHYS2 * | 239 | 57% | 26 | 41% |
| Passed PHYS2 * | 212 | 51% | 22 | 34% |

* Points at which the female and male percentages are significantly different at the .05 level.

** Points at which the female and male percentages are significantly different at the .01 level.

Table 17

ANOVAs of the DATMech Scores by Gender by Persistence

F85 Group

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 793 | 3 | 264 | 8.088 | .000 |
| Gender | 754 | 1 | 754 | 23.075 | .000 |
| PERSIST2 | 53.73 | 2 | 26.87 | .822 | .441 |
| Main Effects | 795 | 4 | 199 | 6.035 | .000 |
| Gender | 747 | 1 | 747 | 22.701 | .000 |
| PERSIST3 | 55.39 | 3 | 18.46 | .561 | .641 |

Table 18

ANOVAs of the DATMech Scores by Gender by Persistence

Combined Group

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 2146 | 3 | 715 | 12.810 | .000 |
| Gender | 2064 | 1 | 2064 | 36.966 | .000 |
| PERSIST2 | 32.36 | 2 | 16.18 | .290 | .749 |
| Main Effects | 2220 | 4 | 555 | 9.926 | .000 |
| Gender | 2046 | 1 | 2046 | 36.578 | .000 |
| PERSIST3 | 106 | 3 | 35.53 | .635 | .593 |

Table 19

ANOVAs of the TOOLS Scores by Gender by Persistence

F85 Group

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 37071 | 3 | 12357 | 15.701 | .000 |
| Gender | 35475 | 1 | 35474 | 45.073 | .000 |
| PERSIST2 | 378 | 2 | 189 | .240 | .787 |
| Main Effects | 37907 | 4 | 9477 | 12.027 | .000 |
| Gender | 35086 | 1 | 35086 | 44.527 | .000 |
| PERSIST3 | 1214 | 3 | 405 | .514 | .673 |

Table 20

ANOVAs of the TOOLS Scores by Gender by Persistence

Combined Group

| Source of Variation | Sum of Squares | Df | Mean Square | F | p |
|---|---|---|---|---|---|
| Main Effects | 92091 | 3 | 30697 | 39.928 | .000 |
| Gender | 88915 | 1 | 88915 | 115.653 | .000 |
| PERSIST2 | 547 | 2 | 274 | .356 | .701 |
| Main Effects | 95643 | 4 | 23911 | 31.343 | .000 |
| Gender | 88464 | 1 | 88464 | 115.962 | .000 |
| PERSIST3 | 4100 | 3 | 1367 | 1.791 | .148 |